Interim Progress Report submitted to
NOAA's Human Dimensions of Global Change Research (HDGCR) Program

Project Title	Decision-making in Agricultural Production in the Argentine Pampas: Alternative Choice Process Formulations and the Value and Design of Climate Information
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I. Preliminary Materials

A. Project Abstract

The emerging ability to forecast regional climate based on El Niño Southern Oscillation (ENSO) offers agricultural decision-makers the opportunity to mitigate unwanted impacts and take advantage of expected favorable conditions. However, efforts to foster effective use of climate information in agriculture must be grounded in a firm understanding of the goals, objectives and constraints of decision-makers in this system for three reasons. First, estimates of the economic value of climate information and forecasts (that help justify public investment) should be based on models closely linked to observed decision processes, rather than on the frequently used prescriptions of normative models. Second, the goals and objectives of farmers' decisions (i.e., their objective functions, in decision theoretical terms) influence how climate information is used and, in turn, how climate information should be presented and communicated. Decisions on the current contents and formats of climate forecasts make implicit assumptions about what farmers are trying to achieve and how such information will be used. It will be useful to make these assumptions explicit and put them to test. Finally, decision makers in numerous domains have been shown to have poor insight into their own decision processes, goals and objectives. This offers opportunities for interventions to help farmers to enhance their decisions.

The project goal is to understand and model decision-making in agricultural production systems in the Argentine Pampas in the face of climate variability and other risk factors, and in response to improved climate information and climate forecasts. We will place a strong emphasis on understanding the dynamics of human behavior and decisions, particularly with respect to choice

and uncertainty in the context of agricultural production, an important, prevalent, and dynamic climate-sensitive system. Our approach will be based on a combination of modeling and field work. Simulation of decision outcomes (crop yields and economic returns) with and without the benefit of climate forecasts of various types and skill levels will enable estimation of forecast value under different farmer objective functions. Field decision experiments will identify objective functions of a large sample of Pampas farmers and assess the prevalence of decision objectives outside the subjective expected utility model that is conventional in economics.

B. Objective of Research Project

The project goal is to understand and model decision-making in agricultural production systems in the Argentine Pampas in the face of climate variability and other risk factors, and in response to improved climate information and climate forecasts. Our approach will combine modeling and field work, and will involve a diverse research team with a rich diversity of perspectives. Specific objectives include:

- Develop estimates of the value of climate forecasts in agricultural decision-making. These estimates will be based on a range of non-normative goals that go beyond the standard assumptions in economic modeling. We will assess the sensitivity of the expected Value of Information (VOI) to the alternative decision-maker goals.
- Identify objective functions of farmers in the Argentine Pampas and their technical advisors and assess the prevalence of decision objectives outside the subjective expected utility (SEU) model that is conventional in economics. To the extent that we find heterogeneity in objective functions, we will also try to predict the presence or absence of such components as regret, loss aversion, and satisficing as a function of both situational and personal characteristics
- Investigate the implications of the existence of non-normative decision-making among farmers for the design and communication of climate information and forecasts.
- Enhance farmers' insight into their own decision processes and goals by designing interventions, training, and decision aids and support tools.

C. Approach

The work has two major components that are being pursued in parallel, but with continuous interaction. The first component involves the simulation of decision outcomes (crop yields and economic returns) with and without the benefit of climate forecasts of various types and skill levels, and the estimation of the value of climate information under the assumption of different farmer objective functions. The second component includes the empirical identification of objective functions of a large sample of Pampas farmers (as well as their technical advisors) and an assessment of the prevalence of decision objectives outside the SEU model that is conventional in economics.

C.1 Modeling the Value of (Climate) Information

We designed an empirical framework to estimate the economic value of ENSO-related climate forecasts for agriculture. The key components of this empirical framework are biophysical crop simulation models and a whole farm optimization model. We are combining process-level crop simulation models and a stochastic, nonlinear optimization model to estimate farm-level outcomes with and without ENSO information. We then compare the two sets of outcome values to calculate ENSO forecast value. The modeling effort we propose would be an extension of our previous work (Letson et al. 2005).

C.2 Identification of Farmers' Objective Functions

The second component of the work involves the identification of objective functions of a sample of farmers in the Pampas (as well as those of their technical advisors) and a determination of the prevalence of nonstandard-economic decision objectives. We will examine the objective functions of individual farmers and their technical advisors through a combination of carefully designed decision experiments, supplemented by surveys and focus groups. The decision experiments can be designed first as paper-and-pencil exercises and, if promising, they can be computerized to facilitate data collection and provide controlled textual and graphic information about decision tasks. We will also try to predict the presence or absence of components such as regret, loss aversion, and satisficing as a function of both situational and personal characteristics.

D. Matching funds used for this project.

The activities undertaken in this project are complementary of ongoing work in Argentina funded by NOAA's Environmental and Sustainable Development Program that focuses on institutional structures for climate dissemination. NOAA funds are being leveraged by two efforts funded by the National Science Foundation that have goals consistent with the NOAA project. The first NSF project is a Biocomplexity in the Environment, Coupled Natural and Human Systems grant being coordinated by the University of Miami. The second complemnatry project is the Center for Research on Environmental Decisions, funded by NSF under the Decision-Making Under Uncertainty initiative. This 5-year effort led by Columbia University involves work on decision-making processes in Argentine farms.

II. Interactions

A. Interactions with decision-makers

Through continued NOAA support, we have developed excellent trust and credibility with AACREA (Asociación Argentina de Consorcios Regionales de Experimentación Agrícola), a non-profit farmers' organization with a strong focus on dissemination of new technologies. The strong commitment of AACREA to this project is illustrated by the fact that it was selected as one of the main three initiatives for the period 2004-2007 announced by the President of AACREA during the organization's 2004 Congress in Mar del Plata, Argentina (see photograph at the end of this report). The collaboration with AACREA has granted us extremely fluid access to farmers and their technical advisors. AACREA Members join regional groups of 7–12 farmers assisted by a technical advisor. Each group meets monthly, a ready-made opportunity for researchers to interact with group members. During this initial stage of the project we have received strong feedback from AACREA technical advisors, who provided a realistic range of managements that we explored in our simulations of optimal actions under different objective functions.

B. Interactions with climate forecasting community

In this project we have not had specific interactions with the international or Argentine climate forecasting community. Nevertheless, our other ongoing projects involve strong interactions with the Argentine Met Service.

C. Coordination with other NOAA projects

Some co-investigators in this project (Letson and Podestá) also are involved in the Southeast Climate Consortium (a RISA-supported effort). Therefore, there is a fluid exchange of tools, approaches and insights between projects. A specific example is the development of the framework for the estimation of economic value of climate information. Such framework was originally developed for southeastern South America with previous NOAA support. The framework was then used in the RISA project, and several publications resulted from its application. Now, this framework is again being used in South America, but innovative elements are being added, such as the estimation of value of information for alternative objective functions (earlier applications had been based only on the maximization of expected utility).

III. Accomplishments

A. Research tasks accomplished

The research undertaken so far has involved the use of a linked framework of agronomic and economic models to examine the nature and magnitude of differences in the agricultural production decisions identified as "optimal" by maximization of three objective functions respectively associated with expected utility theory, regret and disappointment theories, and prospect theory. Most studies comparing these choice models have focused on (often hypothetical) monetary lottery choices in laboratory studies. However, we are exploring the extent to which these choice theories make different prescriptions for or predictions of behavior in complex, real-world contexts. Much is at stake, since those deviations matter a great deal in terms of what we need from agriculture, such as rural incomes, food security, export earnings and agro-environmental amenities.

The research completed to date has involved three major components: (a) the implementation of a consistent set of formulations for the various objective functions considered, (b) the simulation of yields and economic returns for a realistic range of management options and initial soil conditions for the typical crops in the region, namely maize, soybean, and a wheat-soybean doublecrop, and (c) the use of simulation results as input to optimization procedures that identify "optimal" decisions by maximization of objective functions associated with expected utility theory, regret and disappointment theories, and prospect theory. Each of these components is briefly discussed below.

A.1 Implementation of formulations for objective functions considered

We developed explicit functional forms for objective functions for which accepted forms did not exist (e.g., for regret theory). For functions that are incompatible with widely used optimization tools, we developed equivalent but more tractable formulations. For instance, the discontinuity in the derivative of prospect theory's value function provides a problem for the GAMS optimization software (Gill et al., 2000) widely used by economists. Although other algorithms can handle such discontinuities, they tend to get unstable solutions and users are warned to verify results. We developed an equivalent, but more mathematically-tractable formulation for prospect theory's value function that avoids these problems.

A.2 Simulation of crop yields and economic profits

In close collaboration with AACREA technical advisors, we defined 64 different cropping enterprises that reflect a realistic range of cultivation options for the study area. Each enterprise involves the combination of (a) a given crop (maize, full-cycle soybean and wheat soybean), (b) various agronomic decisions (cultivar/hybrid, planting date, fertilization options), and (c) a set of initial conditions (water and nitrogen in the soil at planting) that result from previous production decisions. That is, several enterprises may be associated with the same crop, although involving different management options. Yields for each enterprise were simulated using the crop models in the Decision Support System for Agrotechnology Transfer package: Generic-CERES for maize and wheat, and CROPGRO for soybean. Simulations assumed no irrigation, a very infrequent practice in the Pampas. For each enterprise, 70 simulated yields were obtained (one for each cropping cycle in the 1931-2001 historical climate record used). Economic outcomes were simulated for a hypothetical 600-hectare farm, the median size of AACREA farms in the Pergamino area, using realistic values for crop prices and input costs.

A.3 Optimization procedure

A whole farm production model was used to identify optimal decisions for the objective functions considered. For each function, a wide range of parameter values was considered. In some cases, the value of a given parameter characterizes a personality characteristic (e.g., degree of risk aversion or loss aversion) that may vary among decision-makers. In other cases, there are no widely accepted values for a parameter, therefore a broad range of plausible values must be considered. The choice variable in the optimization was the vector $\vec{x} = (x_1, ..., x_{64})$ that includes the area in the 600-hectare hypothetical farm allocated to each of the 64 alternative cropping enterprises considered. Different land amounts allocated to the 64 enterprises were considered by the optimization of each objective function. The optimization was performed using algorithm MINO5 in the GAMS software package. Optimal actions were identified separately for land owners and land tenants. Very short land leases (usually one year) provide incentives for tenants to maximize short-term profits via highly-profitable crops. In contrast, land owners tend to rotate crops to steward long-term sustainability of production and soil quality. Given the differences in decision-making goals and constraints between land owners and tenants, we modeled the two groups separately.

B. Preliminary findings

Optimal enterprise allocation differed for the three objective functions and for different parameter values, especially for land tenants, whose enterprise allocation is less constrained. The effects of regret are minor compared to the effects of loss aversion and gain-loss reference point of prospect theory. Our results demonstrate in a non-laboratory decision context that psychologically plausible deviations from EU maximization matter. They can be used to explain observed land allocation decisions inconsistent with EU maximization and to identify segments of decision makers who differ in decision objectives or optimization constraints as the result of socioeconomic/demographic or psychological differences.

C. Papers and presentations

C.1 Peer-reviewed papers submitted

Laciana, C.E., and E.U. Weber. A reformalization of the Prospect Theory value function with a well-defined first derivative. Under review, *Operations Research.*

Laciana, C.E., and E.U. Weber. Correcting expected utility for comparisons between outcomes: A unified parameterization of regret and disappointment. To be submitted, *Journal of Mathematical Psychology*.

Laciana, C.E., E.U. Weber, F. Bert, G. Podestá, X. González and D. Letson. Objective Functions in Agricultural Decision-Making: A Comparison of the Effects of Expected Utility, Regret-Adjusted Expected Utility, and Prospect Theory Maximization. Under review, *Management Science.*

C.2 Abstracts and presentations

Weber, E.U. 2006. The Psychology of Decision making Under Climate Uncertainty. Invited address, World Meteorological Organization (WMO) International Conference: Living with Climate Variability and Change: Understanding the Uncertainties and Managing the Risks. Espoo, Finland, 18 July 2006.

Weber, E., G. Bernaudo, F. Bert, K. Broad, G. Caputo, A. Celis, W. Easterling, H. Herzer, C. Hidalgo, R. Katz, C. Laciana, D. Letson, A. Menéndez, C. Natenzon, L. Núñez, S. Núñez, D. Olson, R. Pulwarty, G. Podestá, B. Rajagopalan, M. Re, F. Ruiz Toranzo, E. Satorre, M. Skansi, and C. Villanueva. 2006. Agricultural Decision-Making in the Argentine Pampas: Modeling the Interaction between Uncertain and Complex Environments and Heterogeneous and Complex Decision Makers. University College London, London Judgement and Decision Making Seminar, 31 May 2006.

Weber, E., G. Bernaudo, F. Bert, K. Broad, G. Caputo, A. Celis, W. Easterling, H. Herzer, C. Hidalgo, R. Katz, C. Laciana, D. Letson, A. Menéndez, C. Natenzon, L. Núñez, S. Núñez, D. Olson, R. Pulwarty, G. Podestá, B. Rajagopalan, M. Re, F. Ruiz Toranzo, E. Satorre, M. Skansi, and C. Villanueva. 2006. Agricultural Decision-Making in the Argentine Pampas: Modeling the Interaction between Uncertain and Complex Environments and Heterogeneous and Complex Decision Makers. Multidisciplinary University Research Initiative (MURI) Workshop on Decision Modeling and Behavior in Uncertain and Complex Environments. Tucson, Arizona, February 27-28, 2006.

Weber, E.U. 2005. Agricultural decision-making under (climate) uncertainty. Invited presentation at Asociación Argentina de Consorcios Regionales de Experimentación Agrícola (AACREA) Headquarters, Buenos Aires, Argentina, 29 November 2005.

Letson, D., G. Podestá, C. Messina and A. Ferreyra. 2005. The Uncertain Value of Perfect ENSO Phase Forecasts: Stochastic Agricultural Prices and Intra-Phase Climatic Variations.

Presented at meeting of Southern Extension Research Activity (SERA-30) meeting, May 19-20 2005, Tallahassee, Fla.

Letson, D., G. Podestá, C. Messina and A. Ferreyra. 2005. The Uncertain Value of Perfect ENSO Phase Forecasts: Stochastic Agricultural Prices and Intra-Phase Climatic Variations. Management Science and Operations Management (MSOM) Seminar, a monthly seminar promoted by two departments at the school of Business Administration at the University of Miami, Management Science (MS) and Operations Management (OM), April 20, 2005.

IV. Relevance to the field of human-environment interactions

A. Describe how the results of your project are furthering the field of understanding and analyzing the use of climate information in decision making

Our work to date has made three types of contributions. (1) We provide explicit functional forms for objective functions for which accepted forms do not exist (e.g., regret theory) or have difficulties for mathematical treatment (discontinuities in prospect theory's value function). Whether explicit functional forms for objective functions do not exist or are in need of improvement, it is important for the decision analytic community to agree on common formulations in order to allow for the replication and comparison of results. We hope that our work contributes to such standardization. (2) This work provides a mechanism to explain observed land allocation decisions that are inconsistent with EU maximization with reference to alternative objective functions. (3) Our identification of the agricultural production decisions that are optimal with respect to the three objective functions (for a broad range of plausible parameter values for each function) will allow researchers to identify different segments of decision makers who might differ in objective functions or optimization constraints as the result of socioeconomic/demographic or psychological differences.

B. Where appropriate, describe how this research builds on any previously funded HDGEC research (i.e., through NSF, EPA, NASA, DOE, NGOs, etc.)

This work is the direct result of previous funding by NOAA (mostly through the Climate and Societal Interactions program), the National Science Foundation (Methods and Models for Integrated Assessment, Biocomplexity in the Environment incubation and multi-year grants), and the Inter-American Institute for Global Change Research (IAI). This support has made possible the current project for several reasons:

1. Long-term support from various sources has given us the unique opportunity to examine in increasing detail the multiple dimensions of the effective use of climate information to support decision-making in climate-sensitive societal sectors. The research activities of the team (including several investigators in addition to those in this specific project) have evolved from exploratory projects (e.g., initial understanding of climate impacts) to highly-specific studies of issues involved in the effective use of information (e.g., this study that provides realistic estimates of value of information based on psychologically plausible choice

processes, a parallel study supported by NOAA-ESD that focuses on the role of institutions in communication of climate information, etc.).

2. Complex problems such as the link between climate variability and decision-making can only be understood by pulling together insights and methods from many disciplines. Previous support has allowed us to assemble a diverse, yet cohesive and well-balanced team of investigators and outreach specialists from a range of disciplines. Long-term support has allowed us the time needed to develop personal relationships and establish some common language. Continued support also has yielded interesting (sometimes hard!) lessons about how to achieve interdisciplinary cooperation, and about the optimal level of creative tension resulting from disciplinary heterogeneity (while avoiding its frustrations).

3. Previous multi-year support from the sources cited above has allowed us to develop trust, credibility, and effective partnerships with relevant stakeholders groups such as AACREA, a non-profit organization of farmers, and operational producers and communicators of climate information such as the Argentine Met Service. The active involvement of these stakeholders has ensured the relevance of the research and has facilitated significantly the research process (e.g., allowing fluid access to farmers for different research activities).

C. How is your project explicitly contributing to the following areas of study?

C.1 Economic value of climate forecasts

Our work improves on previous efforts to assess the value of (climate) information by using several alternative objective functions. Given the growing body of evidence that rational choice models fail as descriptions of information use and choice in almost any contexts where they have been examined, an analysis of the value of climate information under the assumption of more realistic choice models is absolutely necessary and crucially important. Further, the methodology that we have described can be generalized to evaluate the value of other types of information. Our research also advances the constructive engagement underway between economists and psychologists concerning preference elicitation. The two professions have too often failed to engage one another on this topic, despite their mutual concerns with the study of human behavior.

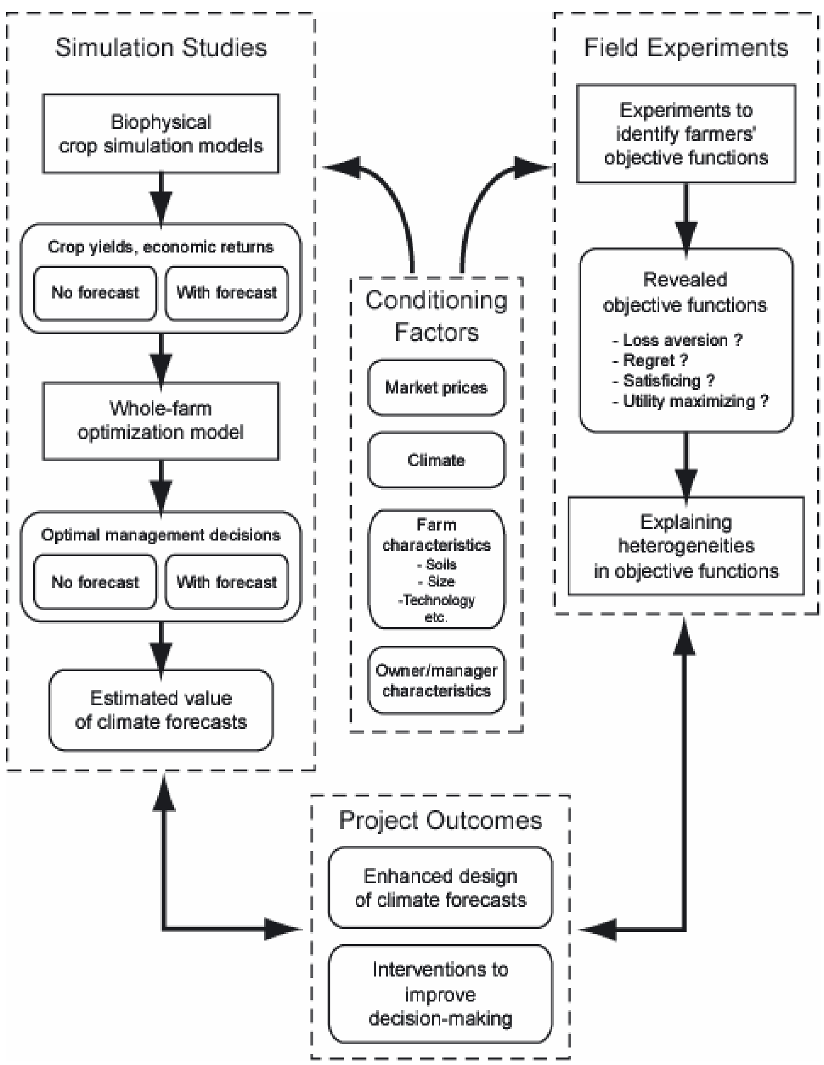
C.2 Developing tools for decision makers and end-users

Uses and users of climate forecasts are heterogeneous: one forecast will not fit all. Information (like climate forecasts) has to be presented in a way that is compatible with users' purpose for using the information, and with their mental model of the task and of the world (i.e., what are they trying to achieve, what things matter, etc.). Identifying the true objective functions used by decision-makers are using will help improve the design of climate information and forecasts. For instance, the notion of regret is very relevant to the assessment of the value of technical innovations, of which people can be expected to be suspicious. Anticipated post-decision regret may, in fact, lie at the root, and help predict the degree of reluctance to adopt new information or new procedures.

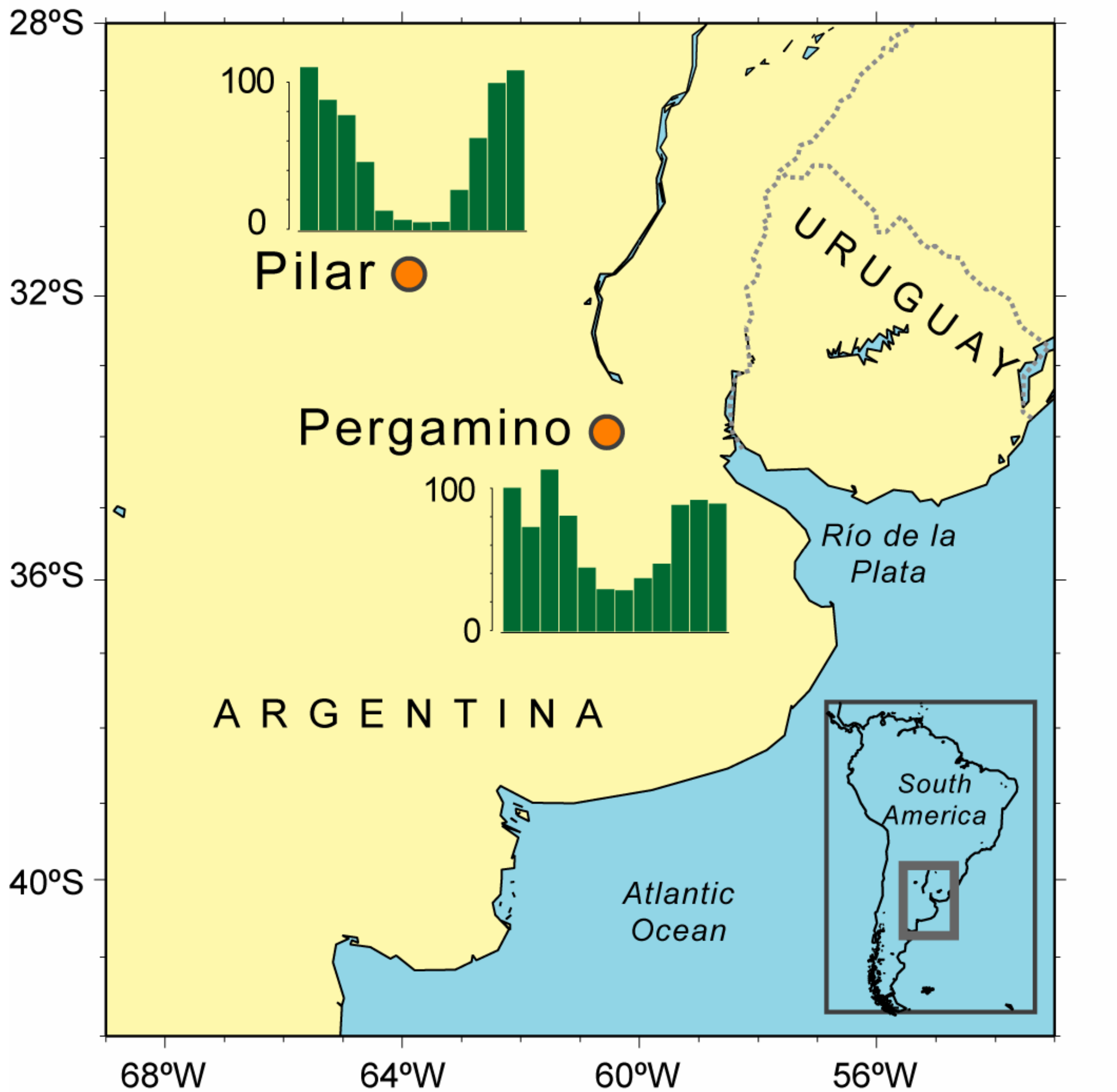
V. Graphics

[Note: Files with these graphics are attached separately]

Overall project framework. Both simulated and observed decisions have a number of *conditioning factors*, including climate, soils, technology, market conditions, what is being produced, ownership characteristics, etc. (a) Simulation studies. *Biophysical crop models* use weather, soil and crop management information to simulate yields, which then can be combined with observed prices to generate estimated economic returns. *Whole farm optimization* selects crop choices and management to achieve a designated objective function. Running the farm model with and without the use of forecast information enables estimation of forecast value. Running the farm model with alternative objective functions evaluates their importance for forecast value estimation. (b) Field experiments. Field experiments will test for the prevalence of deviations from subjective expected utility maximization, particularly loss aversion, regret minimization and satisficing. We will attempt to associate any deviations with the conditioning factors. (c) Outcomes. Any variation or heterogeneity in objective functions we find will bear upon not only forecast value estimation but also on forecast design and dissemination strategies.



Map of the area targeted in the project. The two main locations studied (Pergamino and Pilar) are indicated on the map. The barplots shown next to each location indicate the median monthly precipitation from January to December, computed using data for 1931-2006.



Stakeholder buy-in. Stakeholder participation in this project has ensured the relevance of the science agenda. Sustained funding from NOAA allowed us to develop trust and effective collaboration with AACREA (Asociación Argentina de Consorcios Regionales de Experimentación Agrícola), a non-profit farmers' organization. AACREA plays an important role in the dissemination of new technologies and in many cases replaces the extension role of governmental institutions. The strong commitment of AACREA to this project is illustrated by the fact that it was selected as one of the main three initiatives (and the only research-oriented one) for the period 2004-2007 announced by the President of AACREA during the organization's 2004 Congress in Mar del Plata, Argentina. The photo shows (left to right) Guillermo Podestá (Univ. of Miami), Emilio Satorre and Fernando Ruiz Toranzo (both from AACREA) standing in front of a banner posted at the Congress that reads "Climate forecasts for decision-making. A key project for decision-making and agroecosystem management in the Pampas."

VI. Further information

For additional information, readers are referred to the following WWW site: http://www.rsmas.miami.edu/groups/agriculture.